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High Yielding Variety Bred through Recombinant Breeding Technology in Barnyard Millet (*Echinochloa frumentacea*. L)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Breeding efforts for barnyard millet commenced in the 2009-10 kharif season, focusing on crossing various genotypes. Selection began in the F_2 generation and continued until stabilization was achieved by the F_5 or F_6 generation, requiring a minimum of 6 to 9 seasons to bred high-yielding

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genotypes with insect and disease tolerance. The result is DHBM-23-3, a medium-maturing barnyard millet variety bred at ARS, Hanumanamatti, University of Agricultural Sciences, Dharwad. This variety matures with 85 to 90 days and traits an erect growth habit with a height of 131 to 151 cm. The grains are bold, oval-shaped, and gray in color. DHBM-23-3 has demonstrated impressive yields, achieving 24.12 q/ha for grain and 7.4 t/ha for straw, along with a low shoot fly infestation rate of 2.33%. Compared to the national check varieties, VL-172 and VL-207, DHBM-23-3 exhibits a yield advantage of 13.52% and 14.80%, respectively. From 2011 to 2017, DHBM-23-3 consistently surpassed local and national yield benchmarks, achieving an average grain yield of 41.50 q/ha compared to 27.67 q/ha for RAU-11 and 34.06 q/ha for VL-207. Its performance in All India Coordinated Trials showed continued advantages of 17.63% and 9.23% over genotypes, VL-172 and VL-207, respectively underscoring its adaptability to various agro-climatic conditions. The variety also exhibited strong resistance to key diseases and insects, with a low incidence of grain smut (4.73%) and shoot fly infestation (mean of 2.33%), which can help lower pest management costs for farmers. Nutritionally, DHBM-23-3 outperformed national checks in protein (11.68%), calcium (12 mg/kg), zinc (45.1 mg/kg), and iron (16.2 mg/kg), making it an important food source for addressing dietary deficiencies. Morphologically, it possesses attractive traits, including pinkish pigmentation, a sturdy height of 140 cm, and a bold seed size of 2.67 g, which enhances its marketability. DHBM-23-3 combines high yield potential, robust disease resistance, nutritional benefits, and favorable agronomic traits, making it a promising option for sustainable barnyard millet cultivation across India.

Keywords: Recombinant breeding; barnyard millet; high yielding variety; DHBM-23-3; shootfly; grain smut.

1. INTRODUCTION

Barnyard millet is becoming one of the most important minor millet in the world especially in India because of its multiple uses like food, feed and fodder. It is scientifically named as *Enchinochola* sp. Which contains two major species *Echinochloa esculenta* (Japanese barnyard millet) and *Echininochola frumentacea* (Indian barnyard millet) cultivated for human consumption and livestock feed. Globally, India is the biggest producer of barnyard millet, both in terms of area (0.146 m/ha and production (0.147 mt) with average productivity of 1034 kg/ha during the last 3 years (IIMR 2018). It is less susceptible to biotic and abiotic stresses and mainly cultivated in marginal lands in fragile soils. Barnyard millet is a good source of protein, carbohydrate, fibers and most notable micronutrients like iron and zinc and vitamins. Despite of its agronomic and nutritional benefits, this crop has remained as underutilized orphan crop. Recently, after the establishment of ICAR-Indian Institute of Millets Research (IIMR) and collaborative works with ICAR- National Bureau of Plant Genetic Resource (NBPGR), New Delhi and International Crops Research Institute for Semi-arid Tropics (ICRISAT), Patancheru, Hyderabad the progress has been achieved in the areas like characterization of large number of germplasm resources, identification of trait specific accessions, discoveries of genes/QTL's transcritpome analysis studies, genome sequencing (Japanese barnyard millet) etc. In this article we are highlighting the recent advances in genetic and genomic resources development, and improved technologies in barnyard millet.

Barnyard millet (*Echinochloa* species) is an ancient millet crop grown in warm and temperate regions of the world and widely cultivated in Asia, particularly India, China, Japan and Korea. It is the fourth most produced minor millet, providing food security to many poor people across the world. Globally, India is the biggest producer of barnyard millet, both in terms of area (0.146 m ha^{-1}) and production (0.147 mt) with average productivity of 1034 kg/ha during the last 3 years (IIMR.2018). Barnyard millet is primarily cultivated for human consumption, though it is also used as livestock feed. Among many cultivated and wild species of barnyard millet, two of the most popular species are *Enchinochloa frumentace* (Indian barnyard millet) and *Echinochloa esculenta* (Japanese barnyard millet) (Sood et al., 2015). Barnyard millet is a short duration crop that can grow in adverse environmental conditions with almost no input and can withstand various biotic and abiotic stresses. In addition to these agronomic advantages, the grains are valued for their high nutritional value and lower expense as compared to major cereals like rice, wheat, and maize. It

contains a rich source of protein, carbohydrates, fiber and most notably, micronutrients like iron (Fe) and zinc (Zn) Singh et al., 2010; Saleh et al.,2013; Chandel et al., 2014) that are related to numerous health benefits (Saleh et al., 2013). All these features make barnyard millet an ideal supplementary crop for subsistence farmers and also as an alternate crop during the failure of monsoons in rice/major crop cultivation area (Gupta et al., 2019). Present days need to develop pest and disease resistant high yielding varieties in Barnyard millet. In this aspect at ARS, Hanumanamatti, develop new genotypes in barnyard millet through recombinant breeding technology.

2. MATERIALS AND METHODS

The Barnyard millet genotype DHBM-93-3, developed at ARS, Hanumanamatti, University of Agricultural Sciences, Dharwad, was bred specifically for cultivation in the Indian states of Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, and Tamil Nadu. This genotype was derived from a cross between VL-13, a medium-maturing, non-pigmented variety with a compact ear head and gray seeds, and IEC-566, also a medium-maturing genotype with straw-colored glumes. Elite plants were selected starting from the F_2 generation, and DHBM-23-3 showed superior yield potential and genetic stability among the selected lines. Evaluated alongside local and national standards in station trials at ARS, Dharwad, from 2012-13 through 2014-15, DHBM-93-3 consistently outperformed. Additionally, it was screened for resistance to shoot fly, grain smut, head smut, grain smut severity, brown spot, banded blight, and leaf blight diseases.

3. RESULTS AND DISCUSSION

In a series of evaluations, the barnyard millet cultivar DHBM-23-3 demonstrated a substantial improvement in grain yield over local and national benchmarks. In preliminary yield trials (2011-12) and subsequent station trials (2012-13 and 2013-14), DHBM-23-3 achieved an average yield of 41.50 q/ha, significantly outperforming the local check RAU-11, which yielded 27.67 q/ha, and the national check VL-207, with 34.06 q/ha (Table 1). This represents a yield increase of 49.98% over RAU-11 and 21.84% over VL-207, highlighting its potential for higher productivity. The superior performance of DHBM-23-3 led to its inclusion in the All India Coordinated Trials, where it was further assessed in initial varietal trials in 2014-15, followed by advanced varietal trials during 2015-16 and 2016-17, supporting its status as a promising high-yielding variety for wider adoption (Jali et al., 2012).

Table 1. Performance of new variety, DHBM-23-3 in station trials

Preliminary yield trials	Variety DHBM 93-3 (q/ha)	RAU-11(q/ha)	VL-207 (NC) (q/ha)
1st year	38.50	26.1	35.25
2nd year	42.51	24.8	32.38
3rd year	43.5	32.11	34.55
Mean	41.50	27.67	34.06
Incremental yield (%)		49.98	21.84

Table 2. Summary of seed yield (q/ha) of DHBM-23-3 in All India coordinated varietal trials

Preliminary yield trials	No. of the trials	Proposed variety DHBM-23-3 (q/ha)	National Check 1 (VL-172) (q/ha)	National Check 2 (VL-207) (q/ha)
1st year	8 locations	26.86	19.35	24.11
2nd year	9 locations	22.33	22.20	22.00
3rd year	8 locations	23.18	20.20	20.19
Weighted Mean	25 locations	24.12	20.66	22.10
	Percent increase over checks			
1st year	8 locations		38.81	11.40
2nd year	8 locations		0.58	1.5
3rd year	9 locations		13.52	14.80
Weighted Mean	25 locations		17.63	9.23

Table 3. State wise and year wise grain yield data of new variety DHBM-23-3

State	Year of testing	No. of trials /locations	Proposed variety (DHBM-23-3)	National Check 2 (VL-172)	National Check 1 (VL-207)
Andhra Pradesh	1st year (2016-17)	1	40.87	28.84	15.74
	2nd year (2017-18)	1	36.65	34.05	27.16
	3rd year (2018-19)	1	26.19	18.06	27.18
	Mean		**34.57**	**26.98**	**23.36**
	% increase or decrease over check			**28.13**	**47.98**
Karnataka	1st year	1	49.38	39.01	47.98
	2nd year	1	21.49	31.67	37.53
	3rd year	1	36.54	25.46	26.18
	Mean		**35.80**	**32.04**	**33.89**
	% increase or decrease over check			**11.73**	**5.63**
Madhya Pradesh	1st year	1	22.04	12.96	16.91
	2nd year	1	24.44	27.78	31.67
	3rd year	1	38.27	25.62	27.78
	Mean		**28.25**	**22.12**	**25.45**
	% increase or decrease over check			**27.71**	**11.00**
Tamil Nadu	1st year	3	22.22	13.91	19.94
	2nd year	3	25.36	20.57	17.83
	3rd year	3	12.90	9.23	10.66
	Mean		**20.16**	**14.57**	**16.14**
	% increase or decrease over check			**38.36**	**24.90**

Table 4. Summary grain and straw yield data of Agronomic Trials (2018)

Name of experiment	Item	DHBM 23-3	VL-172 (NC)	VL-207 (NC)
		Grain	Grain	Grain
Fertilizer experiment	Grain yield (kg/ha) under recommended dose of fertilizer F1 (50 %RDF)	1491	1691	1611
	Grain yield (kg/ha) under 100 %recommended dose of fertilizer	1656	2060	1799
	Grain yield (kg/ha) under 125%recommended dose of fertilizer	1985	2300	2042
	Mean	**1710**	**2017**	**1817**

Over three years and multiple trials, the DHBM-23-3 variety consistently delivered an average grain yield of 24.12 q/ha, surpassing the national checks VL-172 and VL-207, which yielded 20.66 q/ha and 22.10 q/ha, respectively. This translates to a yield advantage of 17.63% over VL-172 and 9.23% over VL-207 at the national level, underscoring DHBM-23-3's enhanced productivity and suitability for broader cultivation (Nagarajan and Prasad, 1980). This sustained performance across diverse environments supports its potential as a reliable, high-yielding variety suitable for national adoption and highlights its contribution to improved grain production (Table 2).

The newly developed variety DHBM-36-3 achieves an average grain yield of 23.20 q/ha under rainfed conditions, demonstrating a notable yield advantage that led to its identification by the Varietal Identification Committee during the 29th Annual Group Meeting of ICAR AICRP on Small Millets on April 12, 2018. Following its consistent performance, DHBM-36-3 was officially released and notified in 2022. Its high yield potential across various states in India further solidifies its value as a promising rainfed variety, well-suited to enhance millet productivity in diverse agro-climatic regions (Nirmalakumari and Vetriventhan, 2010).

Table 5. Reaction to major diseases

Name of proposed variety/Hybrid: DHLM-28-4/ LMV-513 **Adaptability Zone :All India**					
Production condition : Kharif and rainfed					
Disease name		**Item**	**Proposed variety (DHBM-23-3)**	**National Check 1 (VL-172)**	**National Check 2 (VL-207)**
Disease 1 Grain smut %	Natural	1st year	7.8	13.6	25
		2nd year	3.4	7.8	12.3
		3rd year	3.0	5.0	5.0
	Mean		**4.73**	**8.8**	**14.1**
Disease 2 Grain smut severity (G)	Natural	1st year	2.5	3.9	3.9
		2nd year	2.7	2.9	3.0
		3rd year	--	-	-
	Mean		**2.6**	**3.4**	**3.45**
Disease 3 Brown Spot (G)	Natural	1st year	**1.5**	1.5	1.7
		2nd year	2.5	2.8	2.7
		3rd year	2.0	2.15	2.2
		Mean	**2.0**	**2.15**	**2.2**
Disease 4 Banded Blight (%)	Natural	1st year	**18.61**	**29.51**	23.4
		2nd year	30.7	22.5	36.2
		3rd year	6.3	58.00	59.0
	Mean		**18.53**	**36.67**	**39.53**
Head smut (G)	Natural	1st year	**0.0**	**0.0**	**0.0**
		2nd year	**--**	**--**	**--**
		3rd year	**--**	**--**	**--**
	Mean		**0.0**	**0.0**	**0.0**
Disease 5 Leaf Blight (%)	Natural	1st year	**--**	**--**	**--**
		2nd year	**--**	**--**	**--**
		3rd year	**3.0**	**3.0**	**4.0**
	Mean		**3.0**	**3.0**	**4.0**

Table 6. Reaction to Insect Pests

Name of proposed variety/Hybrid: DHLM-28-4/ LMV-513 **Adaptability Zone : All India**					
Production condition: *Kharif* and rainfed					
Insect name	**Condition**	**year**	**% Shootfly infestation**		
	Natural		**DHBM-23-3**	**VL-172**	**VL-207**
Pest 1 Shoot Fly (%)		1st year	0.0	0.0	0.0
		2nd year	0.0	0.0	0.0
		3rd year	**7.0**	**14.67**	**23.0**
		Mean	**2.33**	**4.89**	**7.66**

Table 7. Data on Quality Characteristics

Quality Characteristics.	**Item**	**Proposed variety DHBM-23-3**	**National Check VL-172**	**National Check 2 VL-207**
Parameter -1	Zn (mg/kg)	45.1	32.7	29.5
Parameter -2	Fe (mg/kg)	16.2	6.81	10.83
Parameter -3	Ca (mg/kg)	12.0	13.71	6.34
Parameter -4	Protein (%)	11.68	10.41	7.88

State-wise and yearly yield data for DHBM-23-3, shown in Table 3, indicating its strong adaptability and yield performance in key barnyard millet-producing states: Andhra Pradesh, Karnataka, Madhya Pradesh, and Tamil Nadu. To ensure its success in these regions, it is critical for the variety to be resilient to changing climate conditions. DHBM-23-3 consistently produced higher yields, with increases of 28.13% and 47.98% over the checks VL-172 and VL-207 in Andhra Pradesh; 11.73% and 5.63% in Karnataka; 27.71% and 11.00% in Madhya Pradesh; and 38.36% and 24.90% in Tamil Nadu (Selvarani and Gomathinayagam, 2000a). This substantial yield advantage highlights DHBM-23-3's suitability and potential for widespread cultivation in varied agro-climatic conditions across states.

The fertilizer response experiment on the barnyard millet genotype DHBM-23-3 and national checks (VL-172 and VL-207) revealed that DHBM-23-3 demonstrated competitive yield performance under different fertilizer regimes, though it yielded slightly lower than VL-172 and VL-207 (Table 4). When subjected to a 50% recommended dose of fertilizer (RDF), DHBM-23-3 produced a grain yield of 1491 kg/ha, compared to 1691 kg/ha for VL-172 and 1611 kg/ha for VL-207. At the 100% RDF, DHBM-23-3 achieved a yield of 1656 kg/ha, while VL-172 and VL-207 yielded 2060 kg/ha and 1799 kg/ha, respectively (Sharmaet al., 2022) With the highest fertilizer level (125% RDF), DHBM-23-3 reached 1985 kg/ha, with VL-172 and VL-207 yielding 2300 kg/ha and 2042 kg/ha, respectively.

On average, across all fertilizer levels, DHBM-23-3 achieved an average grain yield of 1710 kg/ha, compared to 2017 kg/ha for VL-172 and 1817 kg/ha for VL-207. While DHBM-23-3 showed a slightly lower grain yield performance, it is still competitive under reduced fertilizer conditions, indicating its potential suitability for low-input systems where access to fertilizers may be limited. These results suggest that although DHBM-23-3 may benefit from higher fertilizer applications, its performance under varying fertilizer levels makes it a valuable genotype for regions with less intensive fertilizer use. This adaptability to lower input levels provides an option for farmers seeking resilient and sustainable barnyard millet varieties (Sharmili and Manoharan, 2018).

The proposed variety DHBM-23-3 has shown robust resistance against major diseases affecting barnyard millet, making it well-suited for All India *Kharif* and rainfed production (Table 5). It displayed low susceptibility to grain smut, with an average incidence of 4.73% compared to 8.8% and 14.1% in national checks VL-172 and VL-207, respectively, and a reduced grain smut severity of 2.6 compared to 3.4 in VL-172 and 3.45 in VL-207. Brown spot resistance was comparable, with DHBM-23-3 recording an average severity of 2.0, closely matching VL-172 (2.15) and VL-207 (2.2). Notably, DHBM-23-3 exhibited much lower banded blight infection (18.53%) compared to 36.67% and 39.53% in VL-172 and VL-207, respectively, and remained free from head smut. For leaf blight, DHBM-23-3 showed a slightly lower infection rate (3.0%) than VL-207 (4.0%). These consistent disease resistance levels position DHBM-23-3 as a resilient option for cultivation, offering enhanced stability and productivity in varied environments (Shinde et al., 2018).

The proposed barnyard millet variety DHBM-23-3 exhibited strong resistance to shoot fly infestation compared to national checks VL-172 and VL-207, demonstrating its suitability for *Kharif* and rainfed production across India (Table 6). Over three years of natural infestation, DHBM-23-3 had no recorded shoot fly damage in the first and second years, with an infestation rate of only 7.0% in the third year. This resulted in a low three-year mean infestation of 2.33%, significantly lower than the 4.89% observed in VL-172 and the 7.66% in VL-207. This low mean infestation rate suggests that DHBM-23-3 has a heightened resilience against shoot fly compared to the national checks, which may contribute to reduced pest management costs and lower yield losses for farmers (Sivagamy et al., 2024). Such pest resistance is particularly advantageous for rainfed conditions where pesticide use may be limited, making DHBM-23-3 an effective choice for sustainable cultivation in shoot fly-prone regions.

3.1 Quality Parameters

The newly tested variety DHBM-23-3 demonstrates superior nutritional quality compared to the national checks VL-172 and VL-207, exhibiting higher levels of protein (11.68%), calcium (12 mg/kg), zinc (45.1 mg/kg), and iron (16.2 mg/kg) (Table 7). This analysis indicates that DHBM-23-3 is a nutritionally advantageous choice for consumers. Notably, its zinc content of 45.1 mg/kg surpasses VL-172 by 37.9% and VL-207 by 52.9%, addressing dietary zinc

Table 8. Descriptors of the LMV 513

Sl. No.	Characters	Description
1	Plant pigment	Pinkish pigmentation on nodal region
2	Plant height (cm)	140 cm
3	Days to 50 % flowering (days)	58
4	No. of leaves	55-60
5	Colour of the leaves	Green
6	Leaf length (cm)	38
7	Leaf width (cm)	2.5
8	Midrib colour	Straw colour
9	Glumes colour	Straw
10	Glumes covering	Complete
11	Threshing	Free
12	Seed size	Bold
13	Test weight (g)	2.67
14	Seed colour	Light black
15	Seed shape	Oval
16	Biotic stress	Tolerant to shoot fly

deficiencies effectively. In terms of iron, DHBM-23-3 excels with 16.2 mg/kg, nearly double the iron content found in VL-172 (6.81 mg/kg) and significantly higher than VL-207 (10.83 mg/kg), which is vital for combating iron deficiency anemia. While its calcium content at 12.0 mg/kg is slightly lower than that of VL-172 (13.71 mg/kg), it remains considerably higher than VL-207 (6.34 mg/kg), ensuring a well-rounded mineral profile. Furthermore, DHBM-23-3's protein content is significantly greater at 11.68%, compared to 10.41% in VL-172 and 7.88% in VL-207, underscoring its potential as a protein-rich food source (Sodini et al., 2018). Overall, the impressive nutritional profile of DHBM-23-3 positions it as an excellent option for enhancing dietary health, making it a strong candidate for broader cultivation and inclusion in nutrition-focused food initiatives.

The morphological and agronomic characteristics of the proposed variety DHBM-23-3 reveal its potential for successful cultivation. The variety exhibits distinct pinkish pigmentation at the nodal region, which may enhance its visual appeal and marketability (Table 8). With a plant height of 140 cm**,** DHBM-23-3 demonstrates a robust stature conducive to growth stability and effective light capture. The days to 50% floweringat58 days suggests that this variety has a relatively quick maturation period, allowing for timely harvesting and potentially facilitating double cropping in suitable regions. The leaf count of 55-60 indicates a healthy photosynthetic capacity, which can contribute to overall biomass production. DHBM-23-3 features green leaves with a length of 38 cm and a width of 2.5 cm, providing a favorable leaf area for photosynthesis. The straw-colored midribandstraw-colored glumes (with complete covering) indicate good aesthetics and potential resistance to environmental stressors such as extreme sunlight and rainfall, which can protect the seeds during growth and maturation. The threshing ability is classified as free, indicating ease of harvesting, which is an essential trait for farmers aiming to reduce post-harvest losses (Vetriventhan et al., 2020). The seed size is bold, with a test weight of 2.67g**,** indicating a robust seed that may perform well in terms of germination and yield potential. The light black seed color and oval shape are desirable traits that align with consumer preferences and market standards. Importantly, DHBM-23-3 is noted for its tolerance to shoot fly, a significant biotic stress factor, making it a suitable option for cultivation in regions prone to this pest. Overall, the combination of these morphological traits and biotic stress tolerance positions DHBM-23-3 as a promising variety for farmers, offering not only the potential for higher yields but also enhanced resilience against biotic threats, ultimately contributing to food security and sustainable agricultural practices.

4. CONCLUSION

At the national level, the barnyard millet variety DHBM-23-3 consistently outperforms the checks, OLM-203 and BL-6, in terms of both grain and fodder yield across various growing regions in India, with the exception of Uttarkhand. Additionally, DHBM-23-3 demonstrates strong

resistance to key diseases, including shoot fly, grain smut (with an incidence of 2.46), grain smut severity (1.46), head smut (0.0), brown spot (2.3) and banded blight (32.3%). This resilience allows farmers to cultivate this variety, potentially increasing their income while minimizing environmental impact. In summary, DHBM-23-3 offers significant benefits in yield, disease resistance, pest tolerance, and nutritional quality, making it an excellent choice for diverse agro-climatic regions across India. Its impressive average yield of 41.50 q/ha, along with its consistent superiority over national checks, underscores its productivity potential. With robust resistance to critical diseases and pests, especially shoot fly, DHBM-23-3 provides farmers with a resilient option that decreases reliance on chemical treatments, thus fostering sustainable agricultural practices. Furthermore, its improved nutritional profile—characterized by elevated levels of protein, zinc, and iron—highlights its importance in combating dietary deficiencies. Overall, DHBM-23-3 stands out as a promising high-yielding cultivar that can significantly enhance food security and improve consumer nutritional health.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Chandel G. Meena R., Dubey M. Kumar M., 2014, Nutritional properties of minor millet: neglected cereals with potential to combat malnutrition. *Current Science,* (107) 1109-1111.

Gupta A., Mahajan V, Kumara M. and Gupta H., 2009 Biodiversity in the barnyard millet (*Echninochloa frumentaceac* link Poacea) germplasm in India Genetics Resources crop Evlo. (56) 883-889.

Jali, M. V., Kamatar, M. Y., Jali, S. M., Hiremath, M. B. and Naik, R.K., 2012, Efficacy of value added foxtail millet therapeutic food in the management of diabetes and dyslipidamea in type 2 diabetic patients. *Recent Res. Sci. Tech*. *4*(7): 03-04.

Nagarajan, K. and Prasad, M.N., 1980. Studies on correlation, path, variability in foxtail millet (*Setaria italica* L.). *Madras Agril. J*. *67*(4): 134-135.

Nirmalakumari, A. and M. Vetriventhan., 2010, Characterization of foxtail millet germplasm collection for yield contributing traits. *Electron. J. Plant Breed*. *1*(2): 140-147.

Saleh A, Zhang Q., Chen J., Shen Q., 2013. millets grains in nutritional quality processing and potential health benefits. *Compr Rev Food Science*, *Fodd Saf,* (12) 281-295.

Selvarani, M. and Gomathinayagam, S. P., 2000a, Genetic diversity in foxtail millet [*Setaria italica* (L.) Beauv]. *Res. Crop*, *1*(3): 410-412.

Sharma N, Bandyopadhyay B B, Chand S, Pandey PK, Baskheti D C, Malik A and Chaudhary R. 2022. Determining selection criteria in finger millet (*Eleusine coracana*) genotypes using multivariate analysis. *The Indian Journal of Agricultural Sciences*, *92*(6): 763-68.

Sharmili K and Manoharan S. 2018. Studies on intercropping in rainfed little millet (*Panicum sumatrense*). *International Journal of Current Microbiology and Applied Sciences 7*(2): 323–27.

Shinde, S. S., Karad, S. R. and Kakde, D. S., 2018, Correlation and path analysis studies in little millet (*Panicum sumatrense* L.). *Green Farm*, *9*(1): 21-23.

Singh K.P., Mishra H.N., Saha S., 2010, Moisture dependent properties of barnyard millet grain and kernel. *J Food Eng*. (96) 598-606.

Sivagamy, K., Parasuraman, B., Prasad, S.A., Ananthi, K., Rajesh, M., Sharmili, K., Karunakaran, V., Kumar, A. and Selvarani, A., 2024. Performance of little millet (*Panicum flexuosum*) based cropping system for rainfed agro ecosystems: A path to sustainable crop diversification. *The Indian Journal of Agricultural Sciences*, *94*(4): 427-431.

Sodini, S. M., Kemper, K. E., Wray, N. R. and Trzaskowski, M., 2018, Comparison of genotypic and phenotypic correlations:

Cheverud's conjecture in humans. *Genet*. *209*(3): 941-948.

Sood S., Khulba R., Saini N., Gupta A., Agarwal P.K., 2014, Research Note Interspecific hybrid between *Echinochloaascalenta* (Japanese barnyard millet) and *Echinochloa frementacea* (Indian barnyard millet) A new avenue for genetic enhancement of Barnyard millet. *Electron Journal of Plant breeding*, (5) 248-253.

Vetriventhan, M., Azevedo, V.C., Upadhyaya, H.D., Nirmalakumari, A., Kane-Potaka, J., Anitha, S., Ceasar, S.A., Muthamilarasan, M., Bhat, B.V., Hariprasanna, K. and Bellundagi, A., 2020. Genetic and genomic resources, and breeding for accelerating improvement of small millets: current status and future interventions. *The Nucleus*, *63*(2):217 -239.

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